Using conceptual uncertainty to direct investigations at contaminated sites

Troldborg, Mads; Thomsen, Nanna Isbak; McKnight, Ursula S.; Binning, Philip John; Bjerg, Poul Løgstrup

Published in:
AquaConSoil 2013 - Programme and Book of Abstracts

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

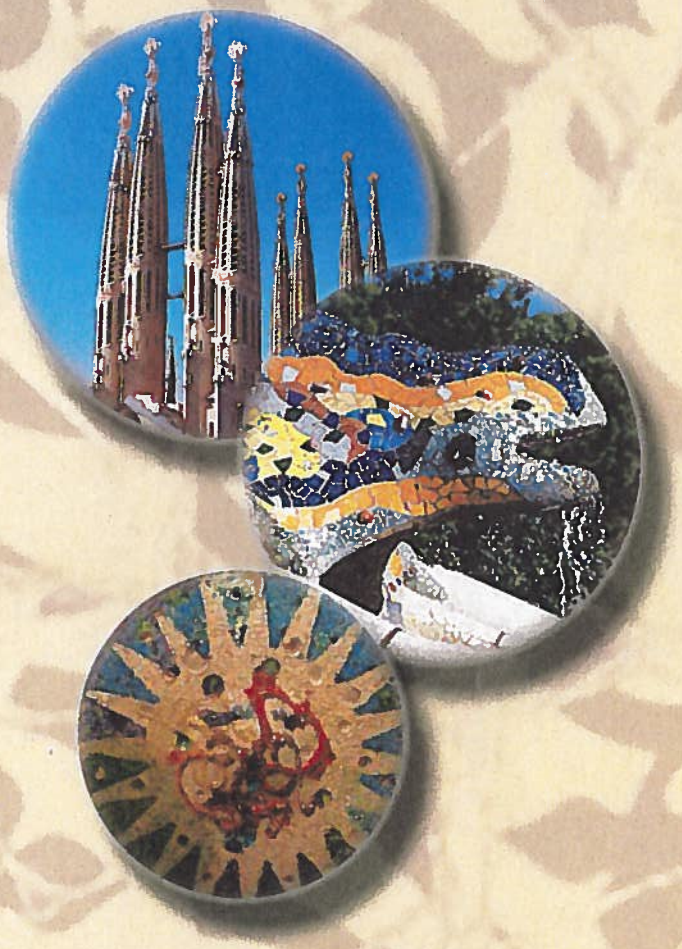
AQUACONSOIL 2013 • BARCELONA

12th International UFZ-Deltares Conference on Groundwater-Soil-Systems and Water Resource Management

16–19 April 2013
Barcelona, Spain

AquaConSoil 2013

www.aquaconsoil.org



PROGRAMME • BOOK OF ABSTRACTS

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Deltares
Enabling Delta Life

Generalitat de Catalunya
Government of Catalonia

Ajuntament de Barcelona

BEFESA

COMSA EMTE
MEDIO AMBIENTE

urbaser

ecocat

- Directly determine the flux by using the Passive Flux Meter
- Directly determine the flux by using the Sorbiflux

In our presentation the different technologies used for estimating/determining contaminant flux as well as the results from the fieldexperiments will be illustrated.

MODELING CONTAMINANT'S FLUX FROM BED SEDIMENTS TO THE WATER COLUMN: COMPARISON WITH PORE-WATER AND PASSIVE SAMPLER FIELD DATA

Iason Verginelli[1], Renato Baciocchi[1], Emma Bianchi[2], Raffaella Borrelli[3], Pietro Cesti[3], Sara Pantini[1], Luciano Zaninetta[4]
[1]University of Rome Tor Vergata, IT
[2]Eni Corporate, IT
[3]Eni Donegani, IT
[4]Syndial SpA, IT

The chemical quality of sediments is typically assessed by measuring the concentration of contaminants in the solid matrix, comparing it with threshold values. This approach, that has been basically extrapolated from common practice in soil remediation, has several drawbacks in the case of contaminated sediments. In fact, for sediments it is difficult to find a robust correlation between total concentration in the sediment of a given chemical compound and its effective impact on both human and ecological receptors. Total concentration does not account for different issues, such as speciation, mobility, availability of a given chemical, that instead may change dramatically its environmental impact. The effective available fraction of a chemical can be estimated either by applying suitable characterization approaches and/or developing suitable fate and transport models to support the characterization step.

To this aim, eni is carrying out a research program aimed to develop a new strategy for sediments characterization in freshwater bodies, that could impact dramatically on the following decision about where, how and at which level set up the remediation activity. This program includes on the one hand the application of passive samplers to evaluate the available fraction of chemicals present in the sediments; on the other hand the development of a model to estimate the flux of chemicals from a contaminated sediment to the water column. This work reports about the development of the model and its application to a case study. The developed 1D dynamic model includes the following sequential pathways: non-linear equilibrium partitioning between sediment and pore water, accounting for black carbon; diffusion, biodegradation and bioturbation through the sediment layer to the pore water-water column interface; diffusion from pore water to water column through the boundary layer; transfer of contaminants to the water column by bed sediments and sediment suspension regulated by the stream velocity and mass balance in the water column. The case study, on which the model has been tested, is a lake located in northern Italy, characterized by sediments contaminated by DDx. Namely, the model was applied to a specific location of the lake, where sediment samples were collected at a depth of 3-10 m, nearby the shoreline. In the same site, PE passive samplers were placed and left for 30 days. The results provided by the model have been used to predict the evolution of the pore water concentration and of the water column concentration, starting from the DDx concentration measured in the sediment, during the exposure period of the PE samplers.

The obtained results highlighted the relevance and the temporal variability of the different processes taking place in the sediment and in the overlying water column. Namely, the comparison of field data with the results obtained by applying the developed model showed that the presence of black carbon (BC) can significantly reduce, by up to two orders of magnitude, the mass transfer from pore water to the overlying water column due to strong binding of the contaminants to BC. The model outcomes also showed that seasonal variation of stream velocity can significantly influence the transfer coefficient and consequently the water column concentration. Namely for local high stream velocity, resuspension could result the main pathway of contaminant release to water column whereas for low stream velocity, contaminant release from sediment beds due to diffusion and bioturbation can result significant. Because of this great local and temporal variability we believe that a combined approach using PE sampler, to estimate the actual contaminants availability in the pore water, and a dynamic model to assess contaminant release from sediment beds in the water column, can provide increased accuracy to predict the fate and transport of hydrophobic chemicals in sediments.

USING CONCEPTUAL UNCERTAINTY TO DIRECT INVESTIGATIONS AT CONTAMINATED SITES

Mads Troldborg[1], Nanna Isbak Thomsen[2], Ursula McKnight[2], Philip J. Binning[2], Poul L. Bjerg[2]
[1]The James Hutton Institute, UK
[2]Technical University of Denmark, DK

Contaminated sites threaten groundwater resources worldwide, but the number of contaminated sites is too large and there are too few economic resources available to ensure a thorough investigation and remediation of them all. Managers are frequently forced to make decisions concerning contaminated site management based on uncertain data and poor site understanding. If poor decisions are made, groundwater quality may deteriorate or money may be spent needlessly on the remediation of sites that do not pose a problem. It is therefore essential to address the uncertainties related to risk assessments and characterization of contaminated sites.

Contaminated site investigation and management usually follows a tiered approach; from the initial identification of contamination, through a number of intermediate investigations, towards a detailed understanding of the mechanisms at site. Through this process the level of knowledge increases and the uncertainty of both the conceptual model and parameters decrease. We present a multi-model approach for estimating the uncertainty of the transient mass discharge from contaminated sites to groundwater, which can be tailored to suit the available knowledge at the site, and thus can improve the foundation of risk assessments. The multi-model approach considers multiple conceptual models for the same site. The different conceptual models consider different source and hydrogeological descriptions where each model is believed to be a realistic representation of the given site, based on the current level of information. Parameter uncertainty is quantified using Monte Carlo simulations. For each conceptual model we calculate a transient mass discharge estimate with uncertainty bounds resulting from the parametric uncertainty. To quantify the conceptual uncertainty from a given site, we combine the outputs from the different conceptual models using Bayesian model averaging. The weight for each model is obtained by integrating available data and expert knowledge using Bayesian belief networks.

As knowledge improves in a site investigation the use of increasingly more sophisticated investigation and modelling tools becomes necessary and costs increase. It is therefore preferable from an economic point of view to safely conclude the investi-

gation at an early stage. This can only be done if it is possible to document with reasonable certainty that there is no unacceptable impact on the groundwater associated with the site. Notably, the multi-model framework can accommodate models of increasing complexity and can be applied at all knowledge levels. If the result of the approach shows that there is no unacceptable impact on the groundwater resource, then site investigations can be concluded. A site investigation can therefore be conducted with a clear picture of the uncertainty associated with the data at all times, allowing better for decisions on when to stop investigation or remediate the site.
We apply the methodology to an actual contaminated site, located west of Copenhagen, Denmark. The site has been used as a storage facility for various chemicals. Heavy contamination with chlorinated ethenes and ethanes, including separate NAPL-phases has been documented at the site. The geology is characterised by clay till underlain by a limestone aquifer; the presence of an upper or secondary aquifer has also been confirmed. This knowledge has been acquired through multiple field campaigns and modelling studies. We test the performance of the multi-model approach at the different knowledge levels to illustrate how the belief in the different models and their input changes with the increasing knowledge available, and how this will impact the predicted mass discharge and management decisions for the site.

MULTI-PATHWAY MASS FLUX EVALUATION OF CONTAMINANT MIGRATION AT AN INDUSTRIAL SITE IN SPAIN

Rachel Sijgers[1], Kevin Leahy[2]
[1] ERM Iberia, ES
[2] Environmental Resources Management, UK

The evaluation of mass flux and mass discharge is gaining increasing acceptance as a valuable tool in the characterization of contaminant migration and increasing understanding of plume behavior. Mass flux calculations quantify the mass of a given contaminant passing through a given profile over time. This information, as opposed to just concentration data, has been used to improve decision making with regards to risk and how it related to remediation planning and the regulatory management of sites. This paper focuses on a specific case where a mass flux evaluation was used to better understand the potential discharge of contaminant mass (chlorinated solvents) from an impacted Tertiary aquifer to a down-gradient Quaternary aquifer and possibly the adjacent river body in Spain.
These calculations were used to assess the potential risk to down-gradient receptors (principally the river) as well as better understand the potential natural attenuation of the migrating contaminants. The site in question is a former manufacturing site where historical subsurface investigations have identified chlorinated solvent impacts in shallow groundwater. The source areas have been remediated, however impacts continue to migrate down-gradient prompting a request by the local environmental authorities to evaluate the potential discharge of contaminants to the Quaternary aquifer and the river. The mass flux evaluation focused on identifying, (1) the pathways or transects across which a majority of the contaminant migration is occurring, (2) the magnitude of this potential discharge and (3) in which of the saturated Tertiary layers a majority of the contaminants are migrating.
Six migration pathways were chosen for evaluation and additional field data were collected to facilitate the mass flux evaluation.
The results identified two principal pathways via which the contaminants were discharging from the Tertiary to the Quaternary aquifer, (1) the horizontal migration between saturated Tertiary and Quaternary layers in connection at the edge of the flood plain and (2) via a subsurface Adit that runs through the Tertiary strata and discharges down-gradient from the Site. This paper summarizes the methodology and results of the multi-pathway mass flux evaluation and how the results informed the decision made by the environmental authorities with respect to the future management of the site. The results in a mass flux context are quite different and more relevant than when only concentrations at single well points are considered.

ThS C1.2 - Human risk

Wednesday | 17 April | 11.00-12.30 | Lecture hall 3

EVALUATION OF THE COMBINED EXPOSURE BY INGESTION OF SOIL/DUST AND INGESTION OF VEGETABLES BY AN INTENSIVE MONITORING CAMPAIGN OF PAH CONTAMINATED SOIL AND VEGETABLES IN RESIDENTIAL AREA

Karen Van Geert, Anja Vandercappellen, Wouter Gevaerts
ARCADIS Belgium nv, BE

Atmospheric deposition is often the dominant pathway for polyaromatic hydrocarbon (PAH) uptake by vegetables grown in urban areas. However, in areas where PAH contamination in soil is present, the contribution of PAH contaminated soil on the vegetables by adhered soil particles is often a dominant pathway and underestimated in modelling. It is too often thought that washing the vegetables will remove all the contaminated soil particles. Advice on vegetable consumption in residential areas contaminated with PAH should therefore be well considered. This study highlights that an intensive monitoring campaign can guide towards reliable advice on potential human health risks.
In this study 10 specific "vegetable gardens" in a contaminated residential area were monitored, as well as 3 references gardens. About 100 plant analyses on PAH were performed, together with 70 soil analyses on PAH. This dataset provided information on the transfer of PAHs in vegetables grown on contaminated soil, on the relation between soil/plant concentration, the effect of washing the vegetables and the effect of the type of vegetables. Additionally, exposure modelling was performed for the evaluation of potential human health risks and to compare modelled versus measured concentrations of PAH for the plant uptake routes.
The PAH profiles differed in the samples depending on the type of vegetables, however, based on the toxicological characteristics and the overall presence of benzo(a)pyrene, this PAH was selected as guidance parameter for the PAH.
The concentration of benzo(a)pyrene in soil ranged between 2 and 16 mg/kg.ds. Concentrations on and in the vegetables ranged between detection limit and 150 µg/kg. After washing, some types of vegetables still had benzo(a)pyrene concentrations of 16 µg/kg. A good correlation of the PAH in soil and plant could be detected, with comparable PAH profiles.
In general, nearly all PAH that were measured on the washed vegetables was the result of remaining fines contaminated with PAH that could apparently not be washed off the vegetables.
The second step comprised exposure modelling, undertaken to (1) evaluate the contribution of the vegetables and the soil ingestion pathway within the total exposure (2) evaluate modelled versus measured vegetable concentrations and (3) give advice on the